Internat. J. Agric. Sci. Vol.3 No.2 June, 2007 : 22-25

Development of rainfall intensity nomograph for Dapoli of Konkan region of Maharashtra, India

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ABSTRACT
The rainfall charts of 14 years of Dapoli were analysed in the form of annual maximum series of various duration, viz. 5, 10, 15, 30 minutes and 1, 3, 6, 12 and 24 hours. The rainfall intensity-duration-return period relationship as $I = KT^a / (t + b)^d$ has been developed for Dapoli, Konkan region under sub-humid high rainfall zone of Maharashtra. The values of parameters a and b were determined by using graphical method and the values of K and d by least square method in the rainfall intensity-duration-return period relation. The values of constants K, a, b and d were found to be 11.08, 0.1892, 1.01, 1.2066 respectively. The nomograph was developed for Dapoli station from intensity-frequency-duration relationship. The per cent deviation in rainfall intensity values observed from mathematical and nomographic solution ranged from (–) 8.3 to 14.2 per cent, which lies with in the acceptable limit. The developed nomograph can be used for computation of rainfall intensity for different duration upto 24 hours for 100 years at Dapoli.

Key words : Nomograph, Intensity-duration-return period relation, Rainfall intensity.

INTRODUCTION

Rainfall intensity is the important parameter need to be determined properly to be used in rational formula. Rational formula, because of its simplicity is being used extensively for estimating peak runoff rate from small drainage areas. In U.S.A. the generalized charts of rainfall intensity-duration-return period developed earlier by Yarnell (1935) and later revised by U.S. Weather Bureau (1961) are being used for obtaining the values of 'I', the rainfall intensity in the rational formula (Ram Babu *et al*. 1979).

Rainfall intensity-duration-return period equation on regional basis can provide solution for computation of rainfall intensity required in estimation of peak flow, which is necessary for design of soil conservation and runoff disposal structures and for planning flood control project (Barai *et al*. 2005). In order to simplify the procedure and to facilitate the computation for field workers the nomograph can prove to be a better option.

MATERIALS AND METHODS

Various equations, that were found to represent the rainfall intensity-duration-return period relationship in India and abroad, were summarized and discussed by Raghunath *et al.* (1969). However the most satisfactory general equation is,

$$I = \frac{KT^a}{(t + b)^d} \quad \text{----------------------- (1)}$$

Where,

I	= rainfall intensity, cm hr^{-1}
T	= return period, year
T	= duration, hr
K, b	= derived constants
a, d	= derived exponents

The altitude of raingauge station located at Wakawali Tal- Dapoli is 167-234 m above MSL. The longitude and latitude are $73^0 16'$ to $73^0 19'$ E and $17^0 19'$ to $17^0 40'$ N, respectively. Climatically the area falls under sub-humid zone. The annual average rainfall is 3525.05 mm. In the present study the rainfall charts of 14 years from 1988 to 2001 of meteorology observatory of the Irrigation Scheme, situated at Central Experiment Station, Wakawali, Tal:Dapoli., were obtained. The rainfall charts were analysed in the form of annual maximum series for various durations viz. 5, 10, 15, 30 minutes and 1, 3, 6, 12 and 24 hours. The maximum depth of rainfall for various durations was worked out employing 'Original trace method' suggested by Ogrosky and Mockus (1957) for all duration (Table 1). Using the rainfall intensities obtained for three different per cent chances, the return period lines were developed and rainfall intensities for 1 per cent (100 years), 2, 4, 10, 25 and 50 per cent (2 years) were obtained (Table 2) and can be considered as observed values of rainfall intensities. The rainfall intensity-duration-return period equation was developed using the following steps (Ram

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Table 1 : Plotting positions for different duration.

Duration, hr	Rainfall intensity, mm/h		
	50% chance line	15.9% chance line	84.1% chance line
0.08	107.87	142.678	81.56
0.16	82.21	112.770	59.94
0.25	79.90	110.560	57.80
0.50	62.50	87.500	44.60
1.00	46.40	66.600	32.30
2.00	30.90	44.100	21.70
3.00	24.60	33.400	18.10
6.00	17.80	25.200	12.60
12.00	11.70	15.850	8.70
24.00	7.70	10.500	5.70

Table 2 : Return period of rainfall intensity (mm hr-1) for different duration

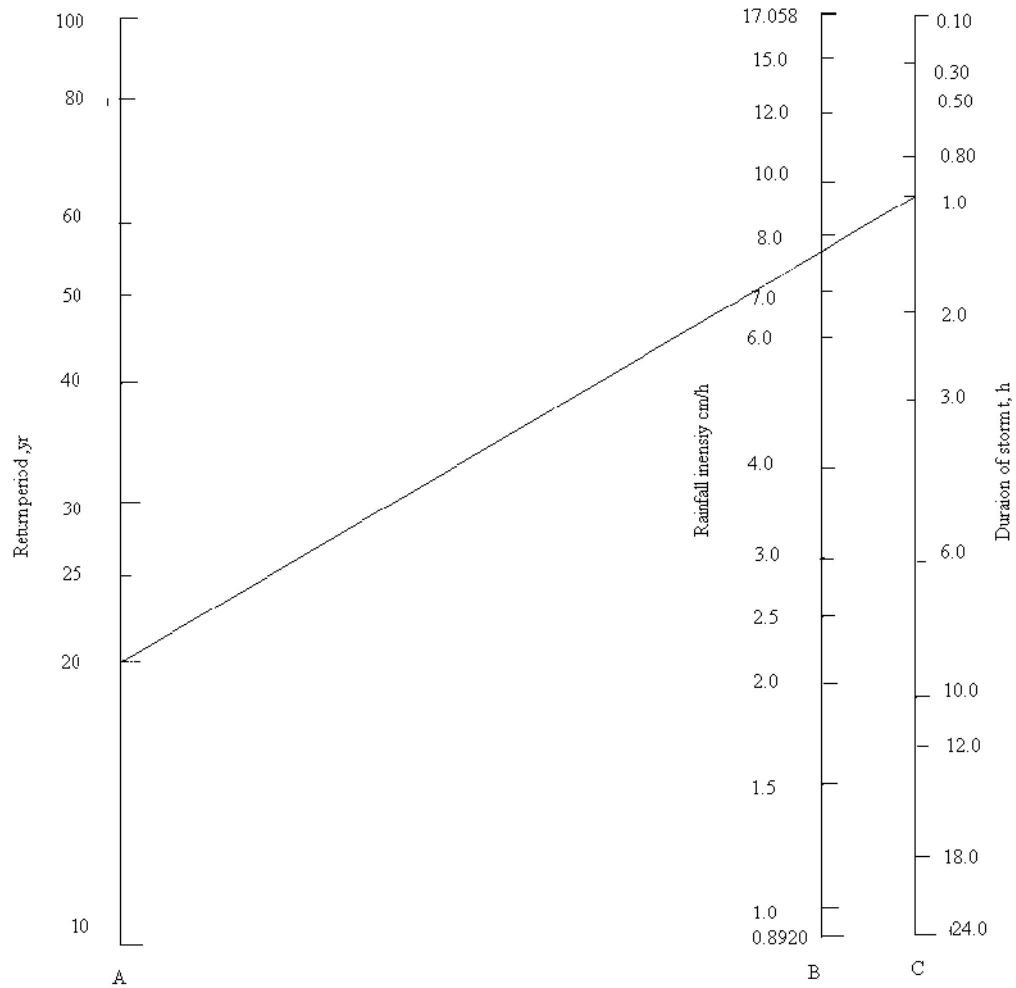
Duration, hr	Per cent frequency					
	1%	2%	4%	10%	25%	50%
	Return period, year					
	100 yrs	50yrs	25 yrs	10 yrs	4 yrs	2 yrs
0.08	200.00	178.950	165.780	144.730	122.630	107.9
0.16	181.25	163.150	142.100	115.780	97.000	82.2
0.25	175.00	152.630	131.570	110.520	90.000	79.9
0.50	143.75	118.420	100.000	80.000	67.500	60.0
1.00	109.73	90.000	77.500	65.850	51.250	46.0
2.00	70.00	60.000	51.000	42.140	33.750	30.0
3.00	52.50	46.660	40.000	33.125	28.180	25.0
6.00	42.00	86.250	30.625	25.000	20.000	60.0
12.00	22.68	18.947	17.368	14.736	20.630	71.5
24.00	15.00	12.630	11.052	9.833	8.333	7.5

Babu *et al.* 1979).

The values of rainfall intensities for all durations were plotted on Y-axis and values of return period on X-axis on log-log paper. The geometric mean slope of the lines represents the exponent ‘a’ in the equation 1. A line representing the geometric mean slope was drawn at the base through origin. The lines parallel to this slope line were drawn by cutting the Y-axis against 1-year return period. The values of rainfall intensities on Y-axis and selected durations on X-axis plotted on log-log paper. The points so plotted are not in a straight line. To align the points into a straight line, suitable constant ‘b’ is to be added to duration. After adding this constant to the values of duration the points were aligned into a straight line. Then the constants ‘K’ and ‘d’ were solved by least square method. The adequacy of rainfall data has been ensured

Table 3 : Computation of minimum acceptable years of record (t_{10} = 1.39 at d.f. = 8)

S. No.	Duration, h	R	Y
1	0.08	1.853	8.589
2	0.16	2.204	10.250
3	0.25	2.190	10.182
4	0.50	2.390	11.167
5	1.00	2.385	11.140
6	2.00	2.333	10.880
7	3.00	2.100	9.746
8	6.00	2.625	12.330
9	12.00	1.972	9.130
10	24.00	2.000	9.270



based on Mockus (1960) criteria as follows,

$$Y = (4.3\ t \log_{10} R)^2 + 6 \qquad \ldots(2)$$

Where,
Y = minimum acceptable years of record,
t = students t test at 10 per cent level of significance
R = ratio of magnitude of 100 years events to 2 years event

The values of 'Y' for all duration obtained from the test of length of record are sown in Table 3.

A nomograph is an alignment chart consisting of a set of suitably graduated parallel scales. The procedure suggested by Luzzadar (1964) was adopted for development of nomograph. In the present study there are three variables viz. rainfall intensity, duration and return period. Thus the alignment chart should have three parallel scales, so graduated that a line which joins values on any

Table 4 : Comparisons between calculated and nomographic intensities of rainfall at Dapoli (cm hr^{-1})

Duration	'i' cal frequency,yr			'i' nomo frequency,yr			σp nomo frequency,yr		
min/h	10	20	50	10	20	50	10	20	50
10min	11.64	13.00	15.34	10.67	12.10	14.29	- 8.30	- 6.90	- 6.84
30min	9.14	10.44	11.66	8.73	9.91	11.70	- 4.48	- 5.07	0.30
1 h	7.20	7.81	9.20	6.92	7.84	9.26	- 3.80	0.30	- 0.05
3 h	4.05	4.31	4.62	3.94	4.47	5.28	- 2.40	3.70	14.20
6 h	2.68	2.87	3.25	2.50	2.84	3.35	- 6.70	- 1.01	2.90

i cal= Calculated intensity of rainfall (cm.hr^{-1}) from developed equation
i nomo= Observed intensity of rainfall (cm.hr^{-1}) from nomographs
σp nomo= Per cent deviation of nomographic values from those calculated by developed equation

two scales intersects the third scale at a point which satisfies he given equation. The developed nomograph for Dapoli is shown in Fig. 1.

RESULTS AND DISCUSSION

Based on the 14 years maximum rainfall intensity data for varying duration, a relationship between rainfall intensity-duration-return periods was developed conforming to the form of equation 1. This relationship for Dapoli is given by equation 3.

$$I = \frac{7.9932 \quad T^{0.1814}}{(t + 1.0)^{0.811}} \text{ ------------------ } (3)$$

Using this equation 3, the intensity for any duration t up to 24 hours and any return period, T up to 100 years can be determined.

Per cent deviation of rainfall intensity values observed from nomograph and those calculated from corresponding mathematical equation for various duration and return period is shown in Table 4. The data revealed that maximum deviation between the nomographic solutions and mathematical equation ranges from (–) 8.3 to 14.2 per cent, which is quite low and acceptable. Such handy tool will be of use for the designers as well as for field workers engaged in soil and water conservation in computing the peak runoff rate using rational formula.

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Received : April, 2006; Accepted : January, 2007